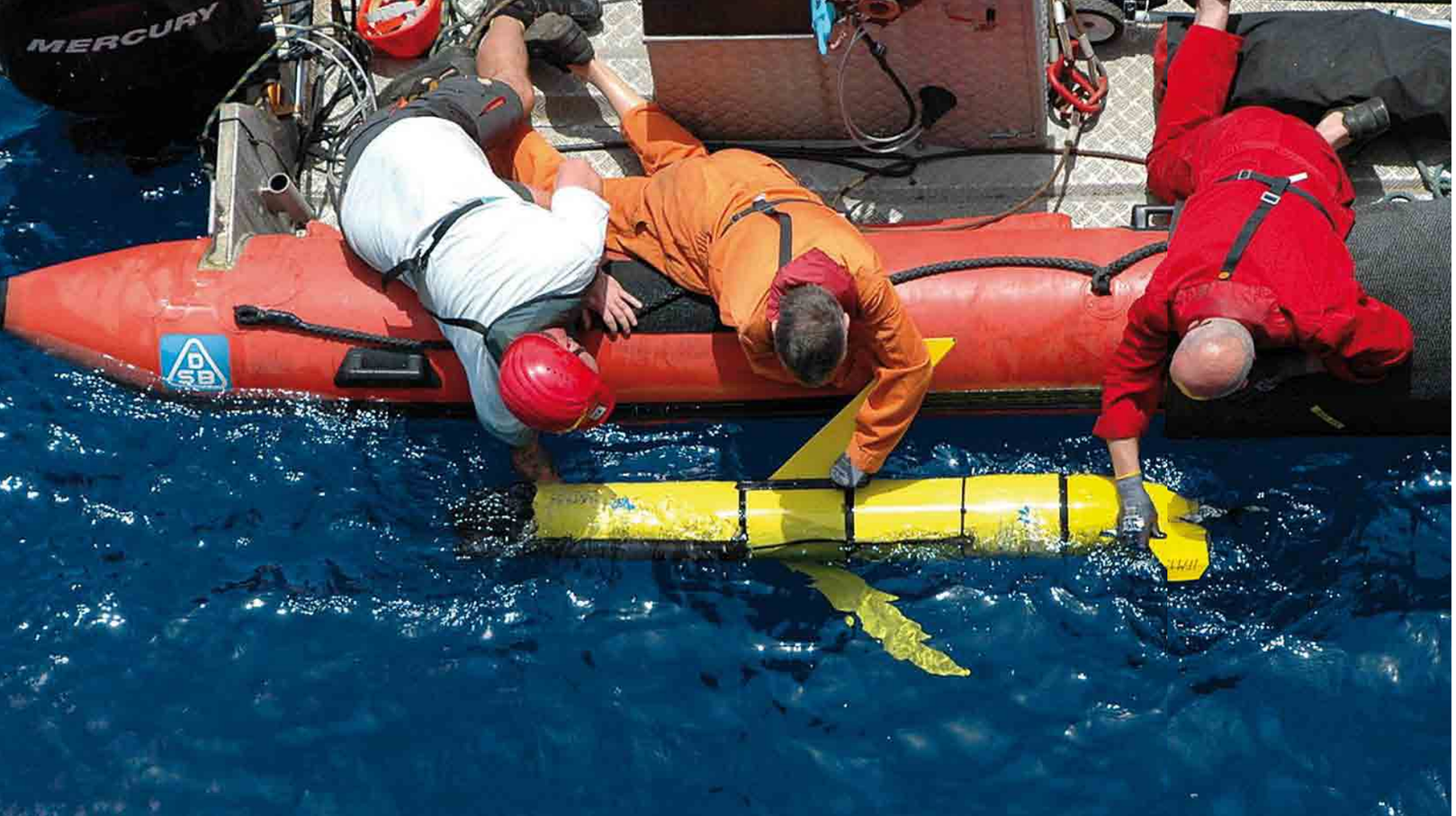
future ocean
KIEL MARINE SCIENCES

BUILDING BRIDGES IN MARINE SCIENCE EDUCATION

The Integrated School of Ocean Sciences



/CONTENT

Cover: Ocean Bottom Electromagnetic (OBEM) station release

Picture: C. Rannou, GEOMAR Helmholtz Centre for Ocean Research Kiel

Prof. Martin Visbeck

Speaker of the Cluster of Excellence "The Future Ocean"
Physical Oceanography, GEOMAR Helmholtz-Centre for Ocean Research Kiel and Kiel University

"Understanding the ocean to sustain our future" is a mission of the Cluster of Excellence "The Future Ocean" in Kiel. Over 250 scientists from all natural science disciplines join forces with economists, lawyers, philosophers, medical scientists, mathematicians and artists in a multi- and even transdisciplinary approach to understanding the ocean and its interactions with humans. Doctoral candidates are central in this endeavour; they drive innovative research, dive deep into the science and are the glue that holds our academic system together. We are committed to providing them with excellent support, cross-disciplinary training and a network of peers, senior scientists and experts from within and outside the University. This has been accomplished within the Integrated School of Ocean Sciences that has generated tangible added value to the marine science community in Kiel.
The ocean has reached the global agenda and an integrated approach to ocean understanding towards sustainable development is needed. We are confident that empowering early career researchers to face these challenges in the 21st century will make a significant contribution to our research in the coming years.

Prof. Markus Bleich

Speaker of the ISOS
Institute of Physiology, Kiel University

PD Dr. Avan Antia

Head of the ISOS

The opportunities and excitement in starting a career in marine science have seldom been so good. Kiel offers a world-class research environment that bristles with the excitement of bridging hard-core scientific research with relevance to society and real-life challenges. Our doctoral programme is committed to enabling and empowering early career researchers to share in this endeavour, to use their personal talents for better scientific output and to consider how best to transition into their next professional step. The result is put together in this brochure.
Our programme is driven by the belief that excellence in education must go beyond academic excellence to include all-round personal and intellectual growth. This means considering all facets of a researcher – the scientist, the entrepreneur, ambitions and perspectives, and the development of personal and professional skills. The programme offers pick-and-choose opportunities in all these areas.
This approach works due to the commitment of senior scientists, the research institutions and enthusiastic support by partners outside of academia – from politics, NGOs, industry and more. We are proud of a vibrant and multifaceted programme and hope you enjoy this brochure.

/ THE ISOS IN BRIEF

/ The Integrated School of Ocean Sciences (ISOS) is the platform for postgraduate education that serves the multi- and trans disciplinary research community in ocean sciences in Kiel, Germany.

ISOS is part of the Cluster of Excellence "The Future Ocean" whose partners are:

Kiel University
GEOMAR Helmholtz Centre for Ocean Research Kiel
Kiel Institute for the World Economy
Muthesius University Kiel

/ Through supplementary training, co-supervision and a focus on career development, ISOS supports the partner institutions in fulfilling their institutional responsibility towards post-graduate education.

/ The programme supports doctoral candidates and supervisors alike. Doctoral candidates access a community from all the natural science disciplines, law, economics, ethics, art and more. They are challenged to see their research in a wider context that includes complex problem-framing in a multidisciplinary environment.

/ The ISOS programme takes a holistic view of research-based education, involving partners from academia, industry, politics, NGOs, and bringing in ad hoc expertise where required. This allows to provide a flexible, need-based programme that is in touch with the system it serves.

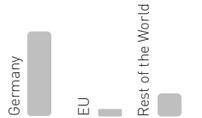
/ An active alumni network provides input to the programme, especially in supporting career perspectives after the doctorate.

150 Doctoral candidates*

55% 45%

180 Supervisors*

Nationality of doctoral candidates*



74% 5% 21%

200 Alumni*

Mean duration of doctoral studies*

4.1 years

*All data from May 2016

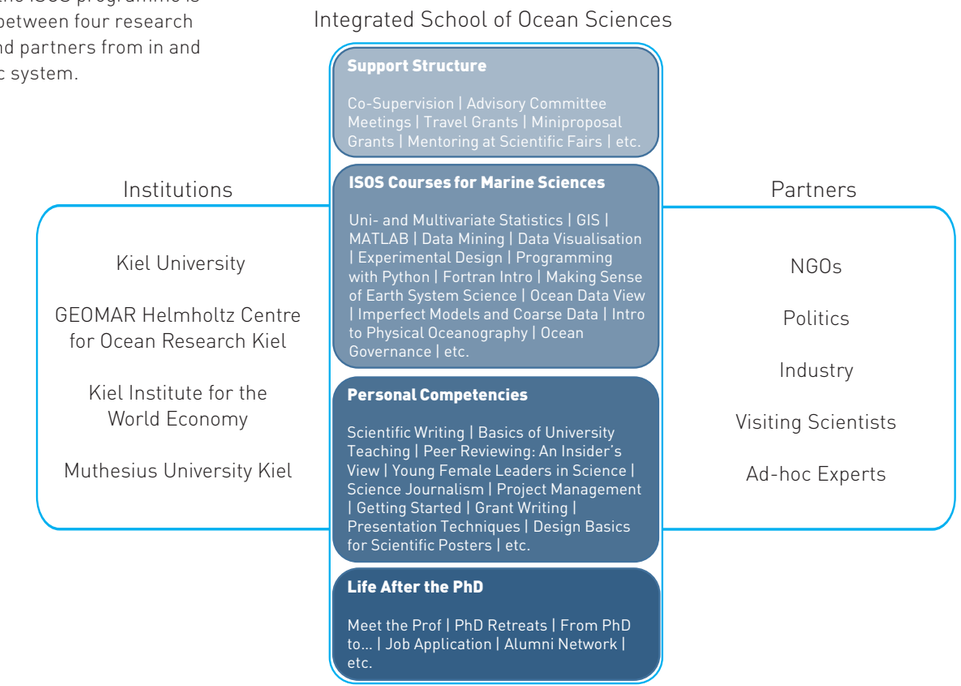
SAMPLING OF COLD-WATER CORALS DURING POSEIDON EXPEDITION 473
Picture: M. Nicolai GEOMAR Helmholtz Centre for Ocean Research Kiel

ROV KIEL 6000 DURING INDEX2013 EXPEDITION

Picture: ROV Team, GEOMAR Helmholtz Centre for Ocean Research Kiel

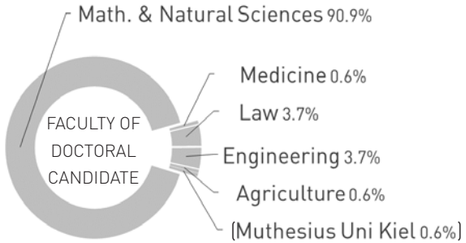
A MODEL FOR POSTGRADUATE EDUCATION

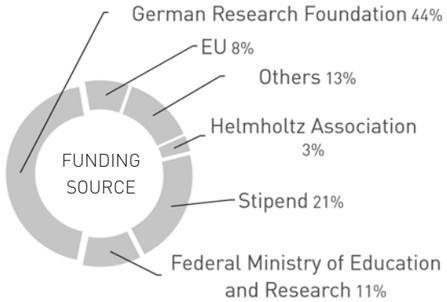
/ The foundation for the ISOS programme is a close cooperation between four research institutions in Kiel and partners from in and outside the academic system.

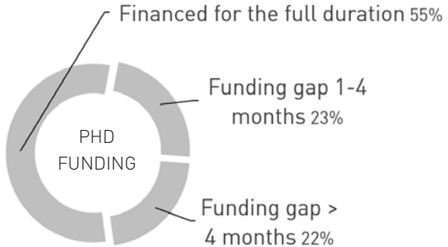


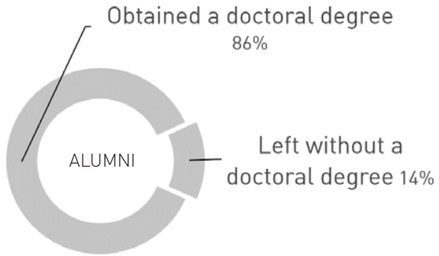
FACTS AND FIGURES*

/ Having a solid database is a prerequisite to identifying the needs of doctoral candidates, monitoring the progress of the programme and providing strategic data to the partner institutions.









*All data from May 2016

MESOCOSM EXPERIMENT KOSMOS 2015

Picture: M. Nicolai, GEOMAR Helmholtz Centre for Ocean Research Kiel

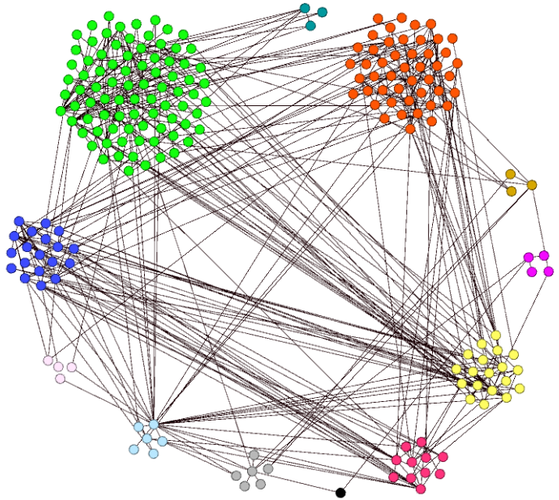
GREEN TURTLE (*CHELONIA MYDAS*)

Picture: R.Scott, GEOMAR Helmholtz Centre for Ocean Research

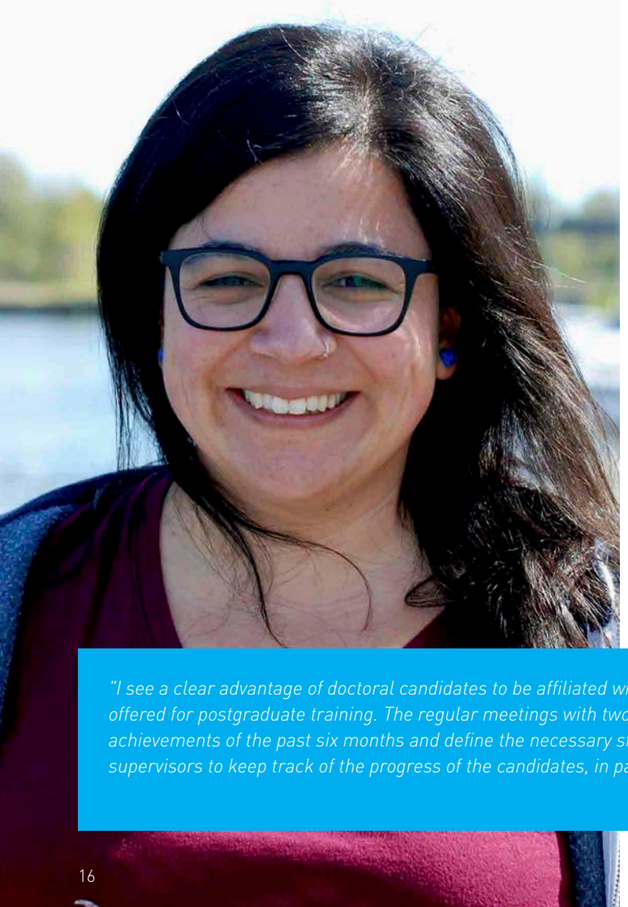
BUILDING BRIDGES IN MARINE SCIENCES

/ The marine research environment in Kiel is characterised by a high level of interdisciplinary cooperation (see graph). In this exciting network, doctoral candidates and supervisors alike benefit from the bridges build between disciplines by the ISOS co-supervision framework.

In the following we profile some of the doctoral candidates, in their own words, to introduce the people behind the network.



Each dot represents a supervisor, each line the co-supervision of a doctoral candidate. ISOS data from May 2016



Zeynep Erdem

Paleoceanography, GEOMAR

"As global warming is happening, ice is melting, and sea level is rising. Earth has experienced such shifts between cold and warm periods many times before. However, anthropogenic activity is making this latest warming way faster than it used to be. What many don't know is that due to warming conditions so-called oxygen minimum zones are also expanding and are limiting the life in the ocean. I am wondering whether this has happened before and what lesson we can learn from the past to understand what is awaiting us? To find out, I look at micro fossils called benthic foraminifera collected from the seafloor off Peru where the largest oxygen minimum zone is observed today. These organisms lived up to 22,000 years ago and recorded changes in their environmental conditions in their shells making them perfect tools to understand the past ocean conditions. Thereby I try to reconstruct how the oxygen concentration changed (or didn't) during the last 20 thousand years at the bottom waters off Peru."

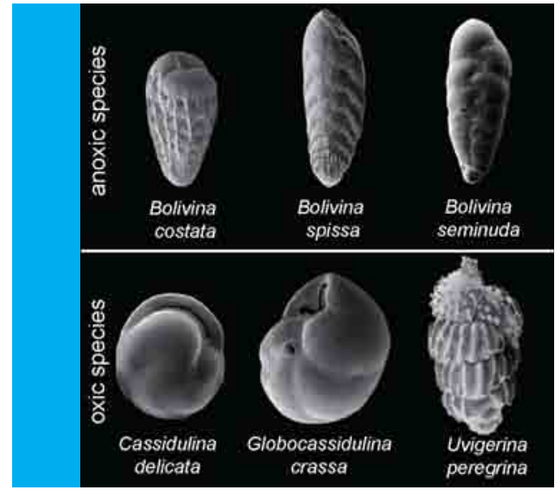
"I see a clear advantage of doctoral candidates to be affiliated with ISOS because of the large variety of courses offered for postgraduate training. The regular meetings with two supervisors are benchmarks reflecting the achievements of the past six months and define the necessary step for the next period. This also helps the supervisors to keep track of the progress of the candidates, in particular when the analytical work takes years."

Dr. Joachim Schönfeld

Reconstruction of the Oxygen Conditions of the OMZ off Peru with Benthic Foraminiferal Studies

The Peruvian Oxygen Minimum Zone (OMZ) is one of the strongest and most pronounced OMZs in today's world ocean and is a key area to study oxygen variations in relation to changing climate. An extension of the OMZ through time and space was investigated using sediment cores from the lower OMZ boundary. Benthic foraminifera have been used as proxies for the prevailing conditions at the sediment–water interface. Variations of bottom water oxygenation can be traced by the downcore distribution of benthic foraminifera and some of their morphological characters. The recent distributions of benthic foraminiferal assemblages provide background data for an interpretation of the past conditions. Living benthic foraminiferal faunas from the Peruvian margin reflect the prevailing bottom-water oxygen concentrations today [1].

The downcore distribution of benthic foraminiferal assemblages showed fluctuations in the abundance of the indicator species depicting variations and a decreasing trend in bottom water oxygen conditions since the Last Glacial Maximum. In particular *Bolivina* species can survive in suboxic environments. In addition, changes in bottom-water oxygen and nitrate concentrations are reconstructed by the pore density in tests of benthic foraminifera [2]. A combination of both proxies provide information on past bottom-water conditions and change of redox conditions for the Peruvian margin.



Frequent indicator species observed in the sediment cores studied. Images by courtesy of Jürgen Mallon, 2012.

References see page 50

Irene Malek

General Microbiology, Kiel University

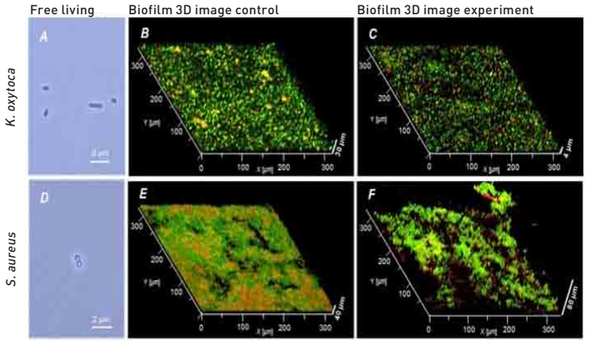
"Bacterial biofilms are literally everywhere, which is unsurprising since evolution took place in a "microbial soup". Virtually all marine organisms host biofilms on their surfaces, most of them essential to health and survival. We know biofilms in other environments too – on shower curtains, sewage pipes and in and on the human body. In my research I ask: which bacteria characterise these films, what are they doing on the surfaces, and how can they be inhibited where they do harm?
To address this I dug deep into my microbiology toolkit, using culturing, metagenomics and confocal laser scanning microscopy to identify naturally occurring compounds that I tested for their ability to inhibit biofilm production and adhesion. I show, for example, the impact of different surface roughness levels on biofilm development. Hopefully this will contribute to stem dangerous bacterial infections by preventing biofilm formation in medical applications."

"While focusing on their own specific PhD topic the ISOS graduate school concept enables the doctoral candidates to take a broader view on their own but also other science projects in a highly interdisciplinary environment. And particularly besides multiple opportunities to broaden one's horizon by participating in interdisciplinary lecture series and soft skill courses the concept allows the students to work in a highly family-friendly scientific environment. Consequently, ISOS is a PLUS in your 'PhD life'."

Prof. Ruth Schmitz-Streit

Elucidating Surface Nanoroughness Levels Concerning their Anti-Biofilm Effects

Contrary to general opinion, bacteria prefer aggregation into biofilms instead of a planktonic life style. To survive inconvenient conditions such as nutrient-limitation, bacteria develop biofilms in four steps - initial attachment, irreversible attachment, maturation and dispersion.
During the initial phase the microorganisms make use of cell-surface components or appendages such as pili and slime to adhere to surfaces and subsequently establish biofilms. This phase of biofilm formation is influenced by numerous factors including the physico-chemical properties of the surface.
We aimed to find the surface roughness with the worst physical properties for bacterial adhesion. To exclude chemical effects we established a moulding technic to fabricate samples of different roughness levels (smooth, 0.3, 1, 3, 9, and 12 µm asperity size) but identical chemical properties. The manufactured samples were inserted into flow chambers. In these small chambers the real environmental conditions are represented by a continuous flow and nutrient supply of the biofilm forming bacteria. After incubation in the chambers we compared the biofilms formed on glass with the ones on the structured surface and visualized the effects using confocal laser scanning microscopy. We analysed the biofilm formation of the rod shaped *Klebsiella oxytoca* and the coccal *Staphylococcus aureus*. *K. oxytoca* biofilms were significantly thinner (reduced to 30 %) on the surfaces with the average asperity size of 1 µm. The biofilm volume was even more reduced (to 5 %). The *S. aureus* biofilm structure was affected by the roughness level of 9 µm. The thickness of those biofilms was reduced to 40 % and the biofilm volume to 6 %. Knowing the affecting roughness levels other surfaces of the same dimensions will be fabricated. Likewise the roughened samples of these surfaces will be inserted into the flow chambers. We are confident that the experiments reveal an anti-adhesive surface suitable for medical application and/or technical devices.



Impact of surface roughness on bacterial biofilm formation. Free living Klebsiella oxytoca (A) and Staphylococcus aureus (D). Control biofilms grown on glass (B & E), and on epoxide resin of different roughness levels (C, 1 µm & F, 9 µm), were stained with SYTO9 and propidium iodide and visualized by confocal laser scanning microscopy.

Corinna Breusing
Evolutionary Ecology of Marine Fishes, GEOMAR

"'Deep, diverse, and definitely different' [1] I couldn't come up with a better description of the largest ecosystem of our planet – the deep ocean. Here, we find some of the most fascinating habitats and species on earth. For me, the most remarkable environments in the deep-sea are hydrothermal vents - oases of life on a deserted ocean floor. Our current understanding of vent habitats and their associated biological communities is still extremely limited. Nevertheless, plans to exploit abundant minerals and extract natural products are already being prepared. These fragile deep ocean islands need to be appropriately managed and I hope my PhD thesis will contribute to the protection of vent biodiversity from imminent human threats."

"The ISOS graduate school concept is not only helpful for the doctoral candidate. It is also a perfect instrument to foster cooperation between working groups, whose PIs are working together supervising the candidate. This way, doctoral researchers are a kind of messenger RNA that initiates more long-term collaboration."

Prof. Thorsten Reusch

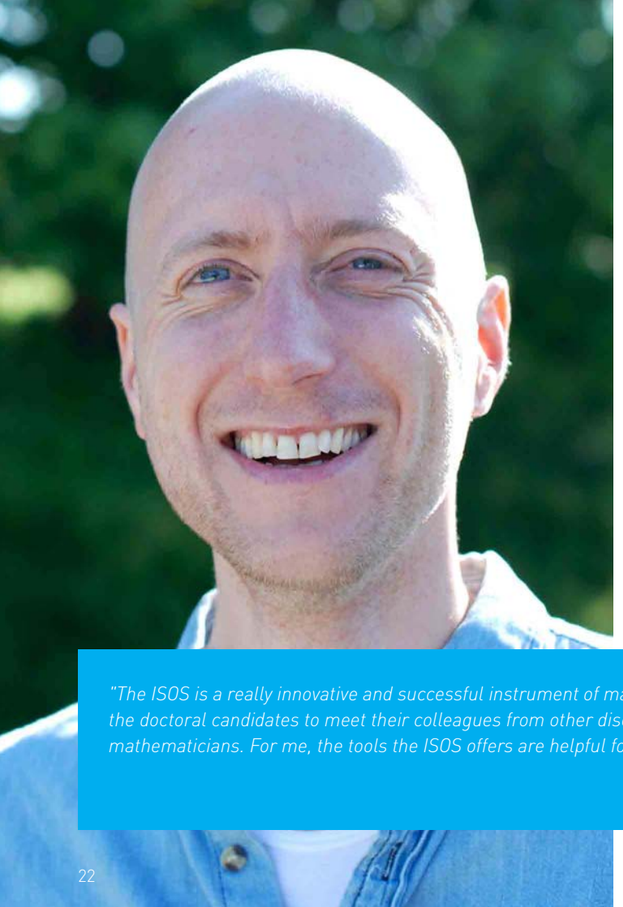
Diversification in the Deep Sea: A Case Study on two Hybridizing *Bathymodiolus* Species

Deep-sea hydrothermal vents are inhabited by specialized communities that live in symbiotic associations with chemosynthetic bacteria. Although it is still largely enigmatic whether and how vent populations at different locations are connected on ecological time scales, increasing human interests in mining of mineral and biological resources put hydrothermal ecosystems at risk. To be able to develop adequate conservation strategies, data on the effective connectivity of vent populations are urgently needed.

In my PhD thesis, I have applied genetic analyses and modelling techniques to assess contemporary gene flow and population structure in ecologically dominant deep-sea mussel species (*Bathymodiolus spp*) from vent systems in the Indo-Pacific and mid-Atlantic Ocean. In contrast to the assumption that the potential for long-distance dispersal of *Bathymodiolus* larvae would allow direct migration between known vent locations, my results indicate that effective population connectivity can only be achieved in an indirect way through the presence of so far undetected mid-way vent sites. Molecular investigations of population structure showed that sampled vent locations of the Indo-Pacific region harbour one broadly distributed *Bathymodiolus* species (*B. septemdierum*), while vent habitats of the Mid-Atlantic Ridge seem to contain four *Bathymodiolus* species with relatively narrow geographic ranges. In both study areas, genetic analyses further suggested the putative evolution of incipient species. While physical barriers appeared to promote allopatric differentiation between an Indian and a West Pacific metapopulation of *B. septemdierum*, patterns of introgressive hybridization between *B. azoricus* and *B. puteoserpentis* implied the formation of a novel hybrid lineage on the Mid-Atlantic Ridge. These findings significantly increase our knowledge on contemporary connectivity, evolutionary diversification and population structure of important deep-sea vent mussel species from the Indo-Pacific and mid-Atlantic Ocean. The results from my dissertation will help to define preliminary environmental management plans to conserve biological diversity at hydrothermal vents.

Bathymodiolus septemdierum. Picture taken at North-West Eifuku Seamount, Pazific Ocean, NOAA

References see page 50



Malte Priess

Applied Mathematics, Kiel University

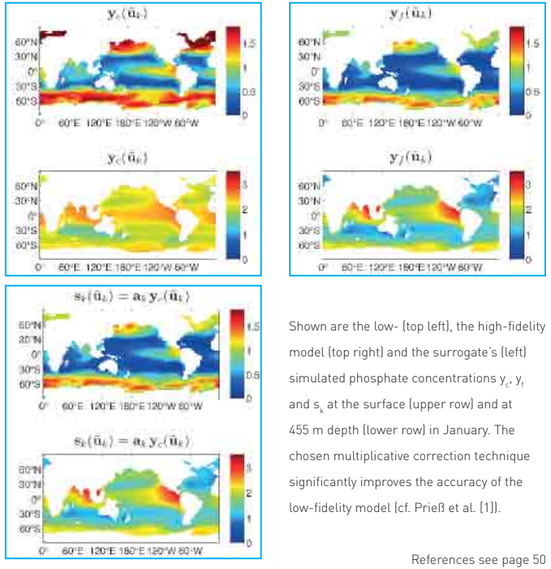
"To understand how the marine ecosystem will respond to climate change and to allow for scientific-based projections of oceanic CO_2 uptake, scientists are highly dependent on marine biogeochemical models and their ability to describe the relevant physical, chemical and biological processes. The quality of a model is therefore typically assessed by its ability to reproduce observed biogeochemical tracer distributions. This usually involves a very time-consuming or even infeasible calibration of the often poorly known model parameters using real observation data. To improve the applicability of state-of-the-art coupled biogeochemistry-circulation models, we aim at finding ways to optimise this calibration process by exploiting faster so-called surrogates. Applying suitable modifications to the models, while not influencing the represented processes, required very close cooperation with scientists from various areas – one aspect I really enjoyed about my thesis."

"The ISOS is a really innovative and successful instrument of marine science education in Kiel. It is a forum for the doctoral candidates to meet their colleagues from other disciplines, which is very useful especially for applied mathematicians. For me, the tools the ISOS offers are helpful for a professional supervision."

Prof. Thomas Slawig

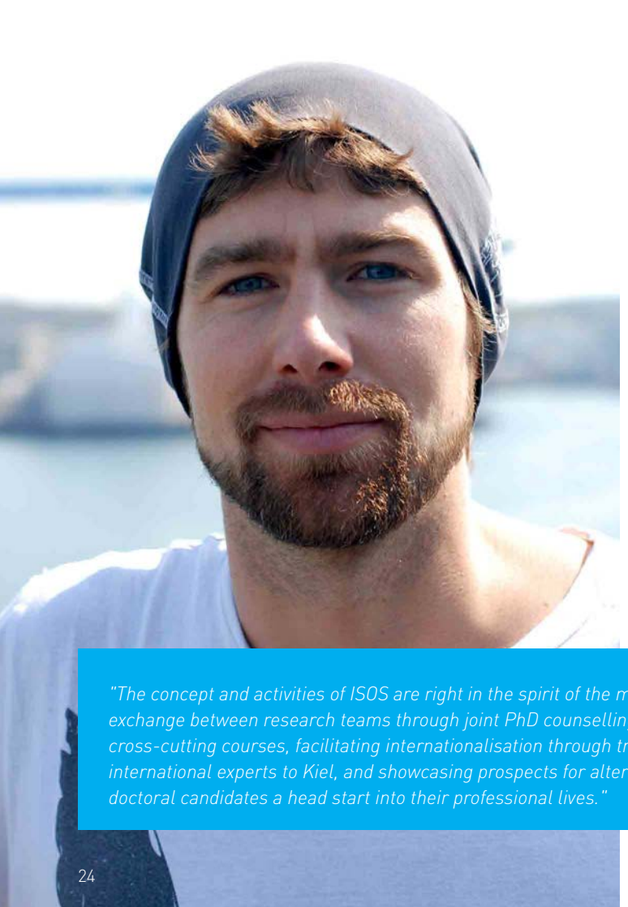
/ Surrogate-Based Optimization for Marine Ecosystem Models

Calibration of marine biogeochemical models is typically performed using conventional optimization algorithms, such as gradient-based, evolutionary or some meta-heuristics. However, one of the fundamental bottlenecks is that typically a large number of often expensive model simulations is required, easily reaching up to several hundreds to thousands of model evaluations. As a consequence, a careful assessment of a model's ability to reproduce observed data by using sophisticated optimization algorithms is still the exception and the development of computationally efficient algorithms, therefore highly desirable. Surrogate-based Optimization (SBO) is a method for acceleration of optimization processes when the underlying model itself is of very high computational complexity. The key idea of SBO is to replace a computationally expensive (high-fidelity) model by a so-called surrogate, which is created from a less accurate but computationally cheaper (low-fidelity) model. Such a surrogate is typically much more accurate than the pure low-fidelity model itself (Fig.1) and thus a more reliable replacement for the original model. Using an SBO approach, the cost of the optimization process can typically be reduced significantly.In Prieß et al. [1], an SBO approach has been successfully applied onto a two-component three-dimensional marine biogeochemical model. Therein, the low-fidelity model we used consists of a reduced number of spin-up iterations (several decades instead of millennia used for the original model). A multiplicative correction operator has been further exploited to extrapolate the rather inaccurate low-fidelity model onto the original one. The proposed SBO technique has been shown to provide a reasonable trade-off between accuracy of the solution and low optimization costs. The method presents a promising and pragmatic tool to calibrate biogeochemical models in a global three-dimensional setting.



Shown are the low- (top left), the high-fidelity model (top right) and the surrogate's (left) simulated phosphate concentrations y_c, y_f and s_k at the surface (upper row) and at 455 m depth (lower row) in January. The chosen multiplicative correction technique significantly improves the accuracy of the low-fidelity model (cf. Prieß et al. [1]).

References see page 50



Michael Sswat
Biological Oceanography, GEOMAR

"Humans and the ocean have a somehow strange connection. We love it for recreational use but at the same time show hardly any respect when exploiting its goods and resources. In addition to direct threats to todays' marine ecosystems, anthropogenic activity will most definitely affect the ocean of tomorrow. I am concerned that we are only now beginning to realise the damage that rising carbon dioxide levels may cause to the ocean's ecosystems. I often find myself wondering how, for example, fish will deal with increasing CO_2 levels. This is why I am really excited to look at how ocean acidification (a result of rising CO_2 levels in sea water) affects the most critical young life stages of herring – one of the most abundant commercial fish species of the world."

"The concept and activities of ISOS are right in the spirit of the marine research environment in Kiel - facilitating exchange between research teams through joint PhD counselling, crossing disciplinary boundaries through cross-cutting courses, facilitating internationalisation through travel support to doctoral candidates and inviting international experts to Kiel, and showcasing prospects for alternative career paths. ISOS is a great asset to give our doctoral candidates a head start into their professional lives."

Prof. Ulf Riebesell

Ocean Acidification and Warming: Impact on Fish Larvae

The effect of increasing carbon dioxide on commercially important fish species is a major concern for future fisheries. Most vulnerable to ocean acidification (OA) is the larval stage, on a physiological level (ossification, organ development and growth) as well as indirectly due to changes in food quantity and quality.
A large-scale mesocosm experiment on ocean acidification using the "Kiel Off-Shore Mesocosms for Future Ocean Simulations (KOSMOS)" was performed in the Gullmar Fjord on the west coast of Sweden. As part of this five-month long study, we investigated the development of herring (*Clupea harengus*) larvae under conditions where both the larvae themselves and the plankton community they feed on were exposed to present-day and future CO_2 levels (projected for the year 2100).

The combined effect of ocean acidification and elevated temperatures under low food conditions was also studied in the laboratory. Here the focus was on the direct effect of ocean acidification on larval growth and development, in combination with increased temperatures. Preliminary results from the lab experiment indicate that the condition of herring larvae (of the same age) is significantly affected under simulated CO_2 levels. In comparison to the effect of temperature, lower survival and condition, the impact of OA on herring larvae is minor, indicating a potential adaptability of herring to elevated CO_2 concentrations, which may already be experienced in their natural environment as a bottom-spawning species.

For the herring in the KOSMOS experiment this would mean that the indirect effect of OA via the food chain could become more important by indirectly affecting larval growth and survival. Altered larval growth and survival would then in turn affect fish populations and therefore fishery yield.

Herring larva 36 day after hatching. Picture taken during the 2013 KOSMOS experiment. Picture by F. Jutfelt (Norwegian University of Science and Technology)

Erik van Doorn
Walther-Schücking-Institute for International Law, Kiel University

"For centuries, our seas were thought to provide unlimited resources and humankind did its best to exploit them. With the increasing perception of depleting marine resources, the call for international regulation of their future use becomes louder. Currently, the status of many marine catch fisheries is deplorable. At the same time, many of these fisheries are based on a system of individual rights for coastal states, fishing communities, fishers or fishing vessels. Why not try to figure out what changes to the legal basis could be made, for example with the help of already existing principles in international environmental law? After all, one of the guiding principles of the law of the sea is the concept of common heritage of humankind, making parts of the ocean exactly that: a common heritage of humankind. And I think we should finally start preserving our heritage for generations to come."

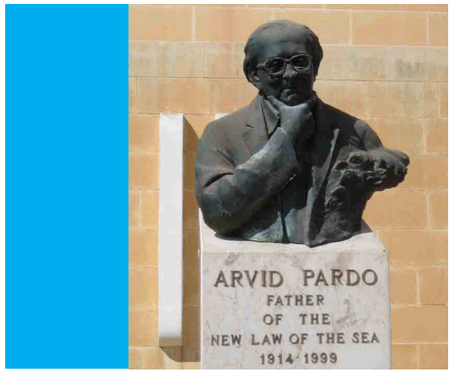
"The regular meetings of supervisors and doctoral candidates that ISOS so strongly encourages help to keep track of the dissertation's progress. In the end, however, it is up to each individual doctoral candidate to bring the project to a satisfactory end. This responsibility is inherent in research on the junior and senior level and cannot and should not be lifted off the shoulders of our doctoral candidates."

Prof. Nele Matz-Lück

Legal Implications of the Common Heritage Principle for Highly Migratory Fish Stocks.

The current status of the world's fisheries is deplorable [1]. Tried concepts seem not to be sufficient to prevent species from over-exploitation, if not extinction. There exist many principles that could be applicable to marine living resources, especially the notion of common heritage of humankind is very important in this regard. Being now mainly applicable to non-living resources, the concept of common heritage of humankind might very well be extended to marine living resources. In fact, the Maltese ambassador to the United Nations Arvid Pardo – who brought the common heritage of humankind and its application to the oceans on the global stage in 1967 [2] - had a much broader application of the concept in mind. Most proposed solutions use individual rights as a basis. This project tries to take a reverse approach and develop a normative framework that is based on the idea of a common heritage.

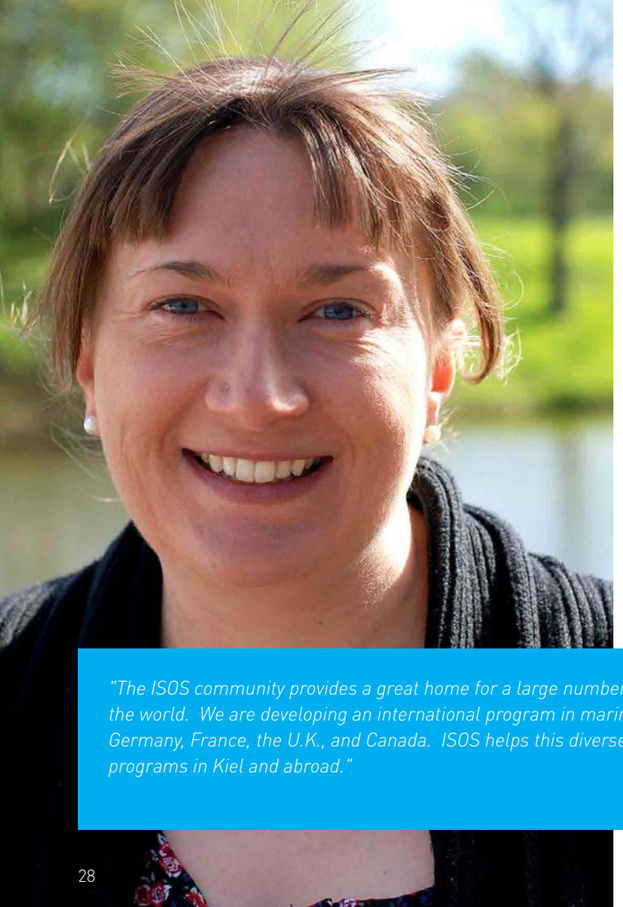
The main question is consequently to what extent the notion of common heritage of humankind and its interaction with other principles of the international law of the sea could provide protection for fish. The five evident characteristics of areas designated as common heritage of humankind are peaceful use, non-appropriation, equitable sharing, protection and preservation for the benefit and interest of humankind, and governance and management by an international authority. Humankind is aware of the ideal of (re)distribution of wealth since time immemorial. Major religions incorporated the idea of stewardship or trusteeship [3]. To discover new opportunities for future ocean governance, this project investigates the interaction of the common heritage principle with the freedom of the high seas, intergenerational justice and the idea of trusteeship.



Picture by Erik v. Doorn.

Notwithstanding the basic assumptions of the present project, marine fish as common heritage of humankind is probably not a realistic solution in the near future, mainly because state sovereignty is still the utmost important pillar of international law. While the significance of statehood is declining and economic factors gain momentum, our approach might have a better chance.

References see page 50



Hannah Grant

Magmatic & Hydrothermal Systems, GEOMAR

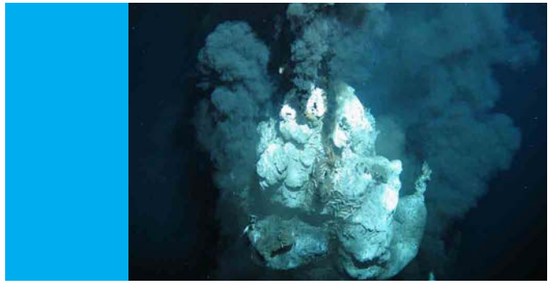
"Have you ever wondered what metals your smartphone contains and where they actually come from? Did you know that at least 50 different metals are used in a typical smart device? As an economic geologist, the source of the metals omnipresent in our everyday lives has long fascinated me. Ever since working on a 2.5 billion year old metal-rich seafloor mineral deposit, I have wanted to go to sea and observe black smoker chimneys forming a similar deposit during the short (geology-wise!) lifetime of a human. The ability to see mineral deposits forming right in front of you, and the idea that they have been developing in a similar way for over 3.5 billion years in Earth's history is something I find amazing! For my PhD I am investigating the behaviour, location and amount of metals in modern seafloor deposits, specifically the 'critical' metals used to drive new technologies. This research is at the frontier of marine resource science, as we do not currently know what resource potential there may be at and below the seafloor."

"The ISOS community provides a great home for a large number of doctoral candidates in my group from around the world. We are developing an international program in marine minerals research with participation from Germany, France, the U.K., and Canada. ISOS helps this diverse group find its way through their respective programs in Kiel and abroad."

Prof. Mark Hannington

Mineralogical and Geochemical Assessment of Seafloor Massive Sulfide (SMS) Deposits at Mid-Ocean Ridges

Black smoker chimneys are the most well-known manifestation of focused, high-temperature 350 °C seafloor hydrothermal activity at mid-ocean ridges [1]. They may be active for hundreds of years, but most of the discharged metals are lost to the ocean in the black smoke of the hydrothermal plume. A more efficient process of forming large accumulations of minerals (i.e., massive sulphides) is from sub-seafloor mineralisation processes that have the potential to form large deposits analogous to those preserved on land. Considering that ocean drilling in kilometres of water depth can cost many millions of euros, we mostly have only surface sulphide samples to study. In order to quantify the amount of metals in large deep-sea sulphide deposits, we need access to drill core.
In 1994, the TAG massive sulphide deposit at 3670 m water depth on the Mid-Atlantic Ridge was drilled to 125 m below the seafloor [2]. TAG is one of the largest known currently forming seafloor massive sulphide deposits and one of very few where samples are available from the sub-seafloor. The drilling also has allowed an estimate of the total amount of sulphides present. In order to interpret the distribution and controls on trace metals in the deposit, my PhD project has focused on analysing sulphide minerals from the drilled sections. I analyse individual sulphide minerals using the micro-analytical technique of laser ablation-inductively coupled-plasma mass spectrometry (LA-ICP-MS). This technique enables the analysis of trace element distributions with a very high spatial resolution, so that the distribution of metals in the deposit can be precisely mapped. The very low detection limits are also crucial to accurate mass balance calculations – especially to determine what minerals contain what metals. If we are interested in one day recovering critical metals from such deposits, we need to know what minerals to extract for that purpose. Laser ablation ICP-MS analysis of metals locked in sulphides in TAG drillcores is being used to track the behaviour of different trace metals in this deep-sea hydrothermal system and is a powerful analytical tool for understanding the overall genesis of the deposit. This is one of the first comprehensive studies of critical metals in a seafloor sulphide deposit, and the first to establish trace metal distribution and behaviour in three dimensions both at and below the seafloor.



Black smoker in the Atlantic Ocean. Picture: ROV Team, GEOMAR Helmholtz-Centre for Ocean Research Kiel

References see page 50

Martin Hänsel
Environmental, Resource and Ecological Economics, Kiel University

"When shaping our common future, global societies have important choices to make. How could we design global and local management strategies to guarantee well-being for future generations within planetary boundaries? My PhD thesis will hopefully contribute one little piece to this fascinating global puzzle in which everything is somehow connected to everything else. Because of all the dynamic linkages between our climate, the ocean and socio-economic well-being, I use integrated assessment models to understand the various social-ecological trade-offs involved when making today's decisions about an inherently uncertain future. There are lots of uncertainties when it comes to potential impacts of climate change - for example species and ecosystem responses or the magnitude of permafrost carbon feedbacks. But did you know that when determining how much climate protection investments should be warranted today, a huge part of uncertainty actually stems from a social, some would argue from an ethical parameter?"

"PhD dissertation work is most productive in a network of peers who are fascinated of similar questions - such as the sustainability of the future ocean. In ISOS, the group of peers consists not only of doctoral students, but also of postdocs and professors in a mutual learning environment."

Prof. Martin Quaas

Intertemporal Distribution of Well-Being and Integrated Assessment

Economic studies of optimal climate policy typically use integrated assessment models to determine an optimal path of emission abatement by means of a cost-benefit analysis. Different studies arrive at remarkably different estimates for the optimal tax rate on carbon emissions into the atmosphere, i.e. the social cost of carbon (Table 1).

	Social Cost of Carbon
Nordhaus (2010) [1]	30 US$/t C
Golosov et al. (2014) [2]	60 US$/t C
Stern et al. (2007) [3]	250 US$/t C

The main reason for these differences are different assumptions about how well-being should be intertemporally distributed. These assumptions are typically embodied in an intertemporal social welfare function used for the evaluation of climate policies. We explore how alternative social objectives on the intertemporal distribution of well-being affect the integrated assessment of climate change. In contrast to the literature that studies alternative parameterisations of a particular social welfare function, we shift the focus and directly assume a parametric form for the intertemporal distribution of well-being. Specifically, we consider a growth rate that linearly decreases to zero in some given time horizon. By varying the time horizon until which the global economy is growing (Fig.1), we study how the desire for growth affects the social cost of carbon. This approach allows us to directly assess the effect of concerns for intergenerational distribution on the social cost of carbon.

Maximizing the short-run growth rate in the deterministic modelling structure of Nordhaus' latest version of DICE, we find that the social cost of carbon increases convexly with the time horizon over which positive, but attenuating, growth in well-being is maintained. While the social cost of carbon in 2015 is US$ 11 for growth over a time horizon of 150 years, it is US$ 140 for a time-horizon of 300 years (Fig. 2). This transparently shows how concerns for intergenerational distributive justice determine the social cost of carbon. Therefore specifying the societal goal with respect to the intertemporal distribution of well-being should be the starting point of any climate change related cost-benefit analysis.

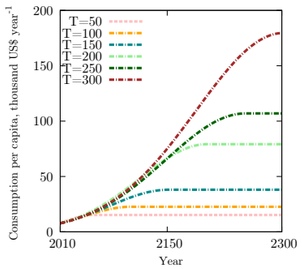


Fig. 1 Time paths (2010-2300) of consumption per capita for T={50, 100, 150, 200, 250, 300}, with initial growth rate optimised.

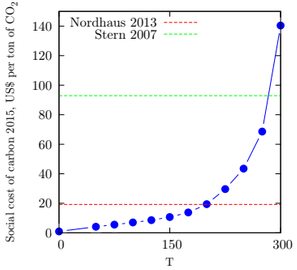


Fig. 2 Social cost of carbon in 2015 as a function of the time horizon T.

References see page 50

Jan-Lukas Menzel Barraqueta
Chemical Oceanography, GEOMAR

"Trace metals in the ocean? What some might mistakenly assume to be pollution is actually one of the essential requirements for almost the entire biomass production in the ocean. Just as humans need trace metals for cellular functioning, marine phytoplankton is equally dependent on iron, zinc or manganese to grow. These tiny algae are the base of the marine food web and without sufficient concentrations of trace metals the whole cascade of marine biomass production would be affected. I am always astonished by the importance of elements that in marine waters are present in concentrations equivalent to a dissolved sugar cube in an olympic-sized swimming pool."

"The ISOS provides an excellent home for our doctoral candidates, with a supervisory meeting schedule which structures their PhD and transferrable skills courses which supports their development outside the immediate research topic. It is also an excellent meeting place for the international group of Kiel marine science doctoral candidates, providing networking opportunities and allowing for new research collaborations to be established."

Prof. Eric Achterberg

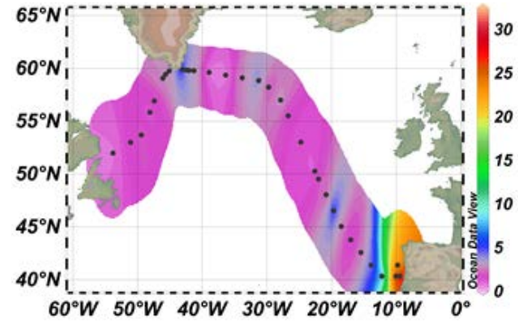
Biogeochemistry of Aluminium in the Atlantic Ocean

My PhD project is involved in the frame of the GEOTRACES project (www.geotraces.org) aiming to create a world map of the distribution of the most important trace metals and isotopes in the world ocean and seas. Trace metals can have different properties and can be used as micronutrients by marine algae, as tracers to quantify process or as proxies for past events that we cannot observe. Samples for dissolved aluminium were taken all over the oceans and measured by Flow Injection Analysis where different reagents mix together, forming a fluorescence complex with aluminium that is afterwards detected on a flourometer. Apart from unravelling the distribution of aluminium in the whole water column, one of the main aims of aluminium determinations is to use it as a tracer of atmospheric dust deposition into the ocean. This can be done with a formula described in Measures & Brown, 1996 [1].

$$G = (A * 0.2 * M * 1000)/(D * S)$$

G = Dust (g m^{-2} yr^{-1}); A = Al concentration (moles $litre^{-1}$); S = fractional solibility; D = molar concentration of Al in dust (moles g^{-1}); M = mixed layer depth (meters); 0.2 = fractional solubility; 1000 = litre m^{-3}

Using this formula, mean dust deposition estimates have been calculated for the North Atlantic from the mixed layer dissolved aluminium samples measured during the GEOVIDE cruise in 2014 (Fig. 1). As observed on the figure, highest dust depositions are found close to the Iberian Peninsula with decreasing dust deposition estimates towards the north west. These results show the expected trend assuming the Sahara Desert as the main source of dust to the North Atlantic Ocean. The results are important as dust deposition is the main source of micronutrients to the open ocean. Direct measurements of aerosol deposition to the open ocean are very scarce, therefore the use as tracers such as aluminium has become very important in order to estimate global dust deposition fields.



Preliminary results of dust deposition estimate (g m-2 yr-1) using discrete dissolved aluminium samples taken in the North Atlantic Ocean. Unpublished results: Menzel et al, 2016. The plot has been done with Ocean data view (Schlitzer, R., Ocean Data View, odv.awi.de, 2015)

References see page 50

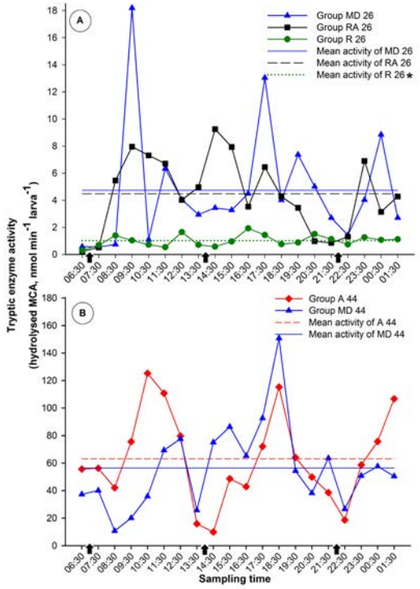
Sinem Zeytin
Marine Aquaculture, Kiel University

"Fish has always been an important protein source for a major part of the global population. With steadily decreasing wild fish stocks and a constantly expanding human population, however, meeting the demand with sustainably produced or caught fish becomes increasingly challenging. I am convinced that sustainable aquaculture can be one part of the solution. That is, if we manage to overcome critical aspects concerning the unstable and unpredictable production of juveniles of many marine fish species. The reliable production of juveniles for aquaculture is a necessity not only to reduce the pressure on wild fish stocks but also to make sure the whole production-circle is cost-efficient. I really like working on the edge between science and industry and I am sure that my thesis can contribute a lot to the optimization of growth and survival rates of marine fish larvae."

"The ISOS program contains not only valuable tools to promote the collaborative approach of the Kiel Excellence Cluster in PhD supervision and candidate mentoring. It also provides manifold options to sharpen the scientific profile and transferable skills of doctoral candidates. Therefore ISOS is unique to prepare and sustain our young talents in the community of marine science."
Prof. Carsten Schulz

Optimization of Growth and Survival of Marine Fish Larvae Under Microparticulate Feed

Knowledge about the dynamics of the diurnal digestive enzyme capacity during early larval stages of fish is crucial for the determination of appropriate feeding time and frequency in captivity. However, there is little data available for only a few species of fish. In this study, several short-term (20 h) diurnal rhythm experiments were conducted under 24 h light conditions to assess the impact of different dietary treatments on the diurnal patterns of tryptic enzyme activity in gilthead sea bream (*Sparus aurata*) larvae. Four different feeding regimes (group fed with rotifers *Brachionus plicatilis* (R), with Artemia (A), with rotifers and Artemia (RA) and with MicroDiet (MD)) were assessed at four different age stages (21, 26, 34 and 44 days post hatch, dph). Experimental groups were fed three times a day at 07:15, 14:15 and 22:15, and only the group fed with MD was fed every 15 min with an automatic feeding system. In addition, for each experiment, a subgroup of larvae deprived of food was evaluated as control. Diurnal variation of tryptic activity in fed sea bream larvae groups showed a clear response on the administration of feed with increasing tryptic enzyme activity response after the feeding events. However, the feeding in the morning and at noon revealed relatively high tryptic activity levels in comparison to the activity after feeding in the evening. In contrast, tryptic enzyme activity remained significantly lower in larvae deprived of food compared to the fed groups throughout the day. Larvae in groups A and MD at 44 dph showed a similar diurnal pattern in tryptic enzyme activity although group MD was fed continuously. The results suggest that no matter what kind of diet was applied sea bream larvae have a limited digestive capacity at a point in time during the day.



(A) and (B) Diurnal patterns of tryptic enzyme activity in different fed groups throughout the short-term experiment. All data are presented as means n=6/sampling time. Black arrows = administration of rotifers and Artemia, MD groups fed every 15 min. Asterik = significant differences (mult.comp test, p<0,05)

References see page 50

SORTING OF DREDGE SAMPLES

Picture: G. Seidel, GEOMAR Helmholtz Centre for Ocean Research Kiel

/ WHAT MAKES THE PHD PHASE SPECIAL?

/ Explore scientific boundaries

During the doctorate, candidates are expected to acquire and demonstrate in-depth scientific expertise and analytical skills. They have the freedom and challenge to explore the boundary of knowledge and step beyond it.

/ Progress towards Independence and Autonomy

The transition from student to self-driven researcher characterises the doctoral phase. Sharp analytical skills, defining new research questions, applying for grants, supervising students are all part of the profile of a successful PhD. These skills are equally important for an academic career as one outside of academia.

/ Participate in the System of Science

Doctoral candidates learn the crucial importance of building a scientific reputation through participation in discourse and peer-reviewed publication. Understanding the academic endeavour means internalising a work ethic of good scientific practice and understanding the nature and philosophy of science.

/ Prepare for "Life after the PhD"

The transition out of the doctorate to a profession in any field is exciting and daunting. At the ISOS, candidates are challenged to step outside of their comfort zone to explore and proactively plan for the future. They meet with experts from all walks of life and realise that they are well equipped to follow their interests and talents.

/ JOINT SUPERVISION

/ Co-supervision is a core component of the ISOS programme. On the one hand it ensures an institutional "safety net", on the other it has proven to be a valued and effective format for cross-disciplinary research.

/ Cross-disciplinary co-supervision of doctoral projects plays an important role in bridging disciplines as well as in educating a cohort of early-career researchers for whom integrated marine research, supported by leading experts, has become part of their profile. Co-supervision by, for example, a lawyer, an economist and philosopher makes Kiel an attractive place for the best young scientists to pursue a PhD.

/ Having more than one primary supervisor enriches the project through different disciplinary views, individual diversity and collegial exchange and support. It gives personal commitment to the doctoral candidate and ensures that the candidate can negotiate stumbling blocks early, allowing them to focus on conducting the best possible science.

BENTHOCOSM EXPERIMENT 2015

Pictures: J. Steffen, GEOMAR Helmholtz Centre for Ocean Research Kiel

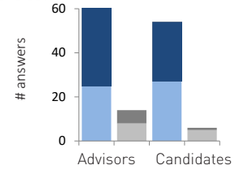
/ ISOS SURVEY ON JOINT SUPERVISION FRAMEWORK*

/ Doctoral candidates and supervisors at ISOS commit to the co-supervision with regular advisory committee meetings. This format is not without controversies so we asked advisors and doctoral candidates for their opinion.

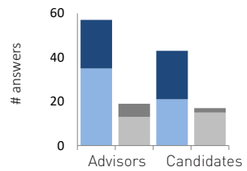
"It is [...] useful to define responsibilities and duties in the beginning of an enterprise (a PhD work), and that can help mitigate or avoid conflict. It will [...]be more helpful for the candidate to know what to expect from a supervisor, but certainly also useful for the supervisor."

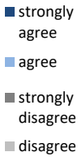
supervisor

Extended supervision in form of an Advisory Committee (AC) is useful *for the doctoral candidate.*

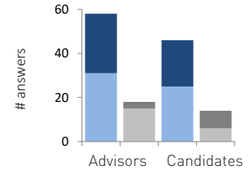


Extended supervision in form of an Advisory Committee (AC) is useful *for the supervisor.*

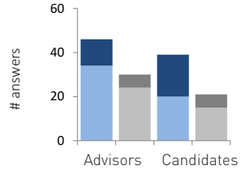




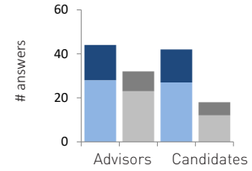
Protocols of the AC meetings are useful *for the doctoral candidate.*



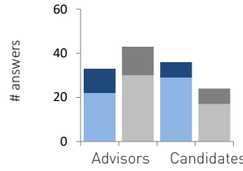
Protocols of the AC meetings are useful *for the supervisor.*



A formalised supervision agreement is useful *for the doctoral candidate.*



A formalised supervision agreement is useful *for the supervisor.*



*Survey data from Nov 2015

/ LOOKING BEYOND THE HORIZON

/ The unique nature of ISOS with a central focus on integrated marine science education and the international network of scientists, doctoral candidates and alumni gathered under its umbrella, provides the basis for building bridges between doctoral research, a diverse spectrum of scientific disciplines and society.

Many ISOS events encourage a view beyond the horizon of the discipline.

/ The Big Questions

Invited scientists and experts give insightful, thought-provoking and personal perspectives about future challenges, objectives and opportunities in their fields.

/ Meet The Expert

Meet the Expert events open the discussion of scientific challenges to a broader range of experts beyond the academic environment. Here, personal perspectives, experiences and ideas from invited guests from outside the academic environment illustrate new approaches to applied marine research.

/ Panel Discussions

Chaired and moderated by doctoral candidates, ISOS regularly hosts panel discussions. Invited guest from politics, academia, NGOs and TV & print media discuss, for example, the role and responsibility of science and scientists in society.

/ Life After The PhD

ISOS dedicates a special focus to career development. Seminars, workshops and retreats provide participants, invited guests and experts with the opportunity to discuss motivation, challenges and the excitement of the life after the PhD.

/ Women In Academia

The recurring ISOS course „Young Female Leaders in Science" addresses the specific challenges for women in academia.

/ Retreats

ISOS retreats focus on a specific aspect of scientific work and/or the doctoral life and encourage the informal exchange of personal experiences. Invited experts come from in and outside academia.

"The ISOS retreat on the "life after a PhD" made me face questions that I usually successfully avoid, and provided the means to start answering them."

doctoral candidate

ISOS RETREAT "LIFE AFTER THE PHD"

Picture: ISOS, Cluster of Excellence "The Future Ocean"

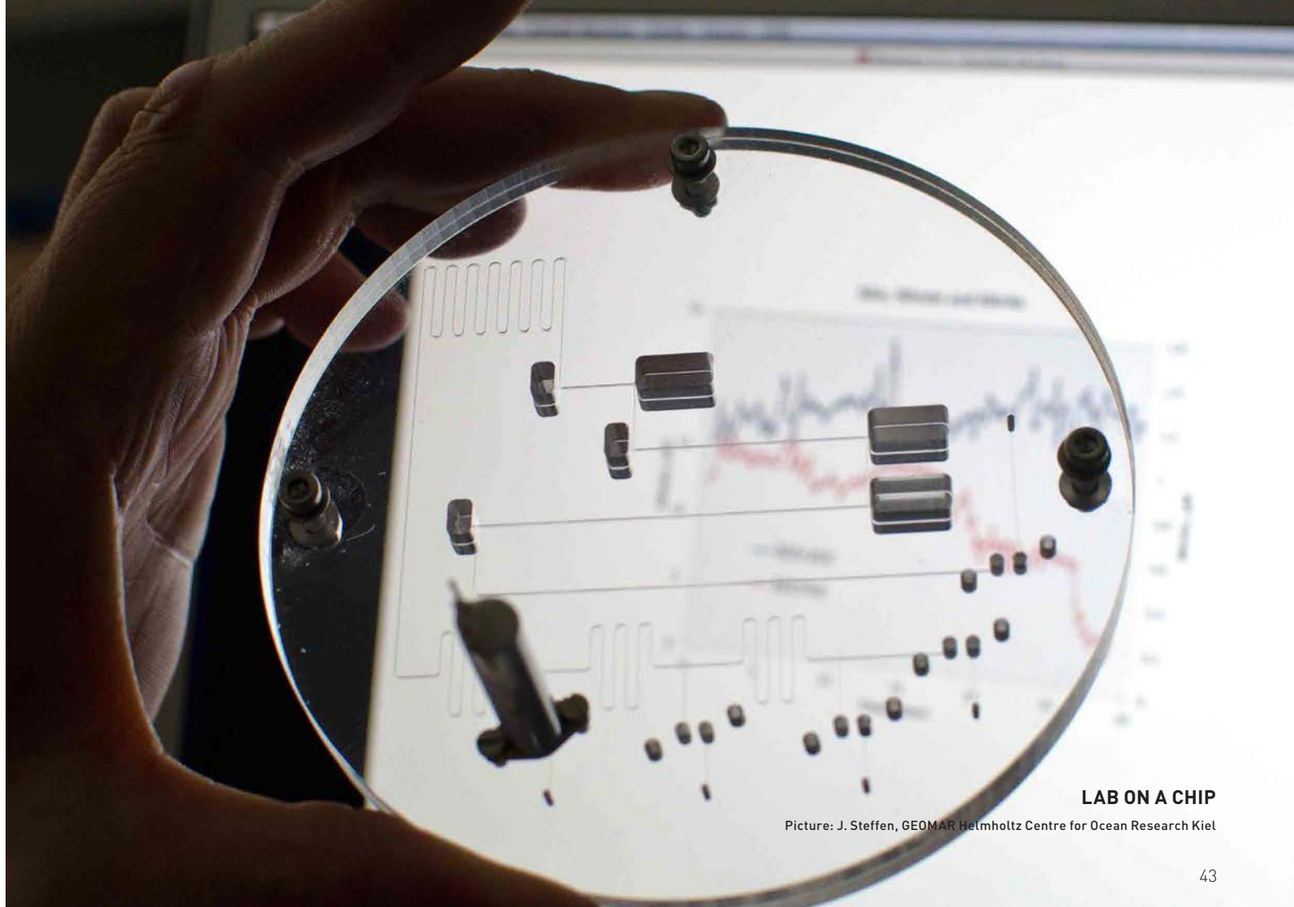
/ FROM IDEA TO RESEARCH PROPOSAL

/ Attracting talented and innovative young scientists to the integrated research environment of marine sciences in Kiel plays an important role in bringing in fresh ideas, encouraging innovative research at an early career phase and creating and extending the unique cross-disciplinary research environment.

/ Twice, the Cluster of Excellence "The Future Ocean" set out to recruit a cohort of early career scientists by not defining projects but rather issuing an open call for doctoral proposals with a particular focus on the interdisciplinary profile of marine sciences in Kiel. Applicants were asked to match their proposal to one research area within the framework of "The Future Ocean" and contact possible supervisors.

/ Over 200 young scientist from around the world responded, proposing to unite, among others, law with fisheries, art with ocean sustainability and ocean modelling with biogeochemistry. Forty high-potentials were than invited to a symposium giving the applicants the possibility to introduce their research idea.

/ Eventually, 19 successful young researchers came forth to join the integrated marine science network in Kiel and add on to the spirit of the Excellence Cluster "The Future Ocean", constituting to a new generation of excellent marine researchers.



LAB ON A CHIP

Picture: J. Steffen, GEOMAR Helmholtz Centre for Ocean Research Kiel

"The Miniproposal gave me the extremely valuable experience of carrying out a project from the idea to its implementation. I learned a lot by designing the set-up, thinking together with technicians [...] about possible ways to implement it and finally coordinating the deployment on the ship."

doctoral candidate

FISHERIES BIOLOGY EXCURSION

Picture: M. Nicolai, GEOMAR Helmholtz Centre for Ocean Research Kiel

/ ISOS PHD MINIPROPOSALS

/ Doctoral research often opens up more questions than it answers. To follow up on those questions, "PhD Miniproposals" allow doctoral candidates to frame and implement their own small research project as a supplement to their doctoral thesis. After consultation with their supervisors, candidates are entitled to hand in a proposal structured similar to the individual grant application of the DFG (German Research Foundation). The proposals are then sent out for external review.

ISOS has granted one "PhD Miniproposal" per year.

/ Miniproposals to date have been:

> "Bathymetry at lake Ohrid for subaquatic slide overview mapping"
> "Developing methods to analyze the physical surface of the combjelly *Mnemiopsis leidyi*"
> "Differential gene expression patterns in response to ocean acidification in larvae of a commercially important fish species, *Gadus morhua*"
> "Phytoplankton food quality responses after long-term exposure to high carbon dioxide levels"
> "Ocean biogeochemistry under changing climate with a phytoplankton optimality-based model"
> "Uncertainty in tropical Pacific climate projections due to chaotic atmospheric forcing and initial conditions"
> "Carbonyl-sulfide cycling in aphotic depths"

"As an ISOS PhD Representative I find it important to bring in the PhD's ideas and needs into the ISOS programme. I see myself as bearer and co-designer and I am looking forward to the exchange with other PhDs"

Kerstin Wittbrodt, ISOS PhD Representative

LOPHELIA CULTURE

Picture: A.Form, GEOMAR Helmholtz Centre of Ocean Research

/ ISOS ADVISORY BODY

/ Regular input and feedback from senior scientists and elected PhD representatives enables us to meet the challenges of providing excellent marine science education in a fast-paced research environment.

/ PhD Representatives

ISOS PhD representatives are part of the advisory body and give a voice to the doctoral community, building bridges between doctoral researchers, the ISOS steering committee and the Future Ocean governing panel. PhD Representatives have a vote in Future Ocean Council meetings. In addition, they encourage networking between doctoral candidates from different disciplines outside their institutions by organising social events for the doctoral community.

/ Steering Committee

Following the integrated research approach of the marine research environment, the steering committee consists of professors from disciplines across the marine sciences in Kiel. The steering committee acts as an advisory body to the ISOS and takes part in evaluation, monitoring and maintaining the quality of the ISOS programme.

/ ISOS ALUMNI PATHS

"Some of the most enlightening things I have experienced during my PhD research came from panel discussions organized by the ISOS."

ISOS Alumna

/ Keeping in touch with alumni of the ISOS programme is important. Via regular newsletters, networking opportunities and their involvement in ISOS activities, alumni coming back bring a world of experience that is constantly used to improve the programme.

/ Alumni help bridge the gab between the active PhD phase and options in professional life thereafter. First-hand experience can help doctoral candidates to accept and master the many challenges of that lie ahead.

/ ISOS activities featuring alumni include

> Retreats
> "From PhD to..." seminar series
> "Meet the Alumni" events

My experience in the Kiel multidisciplinary research environment enabled me to understand the benefits of modelling in non-academic areas, i.e. oil and gas exploration – my current occupation.

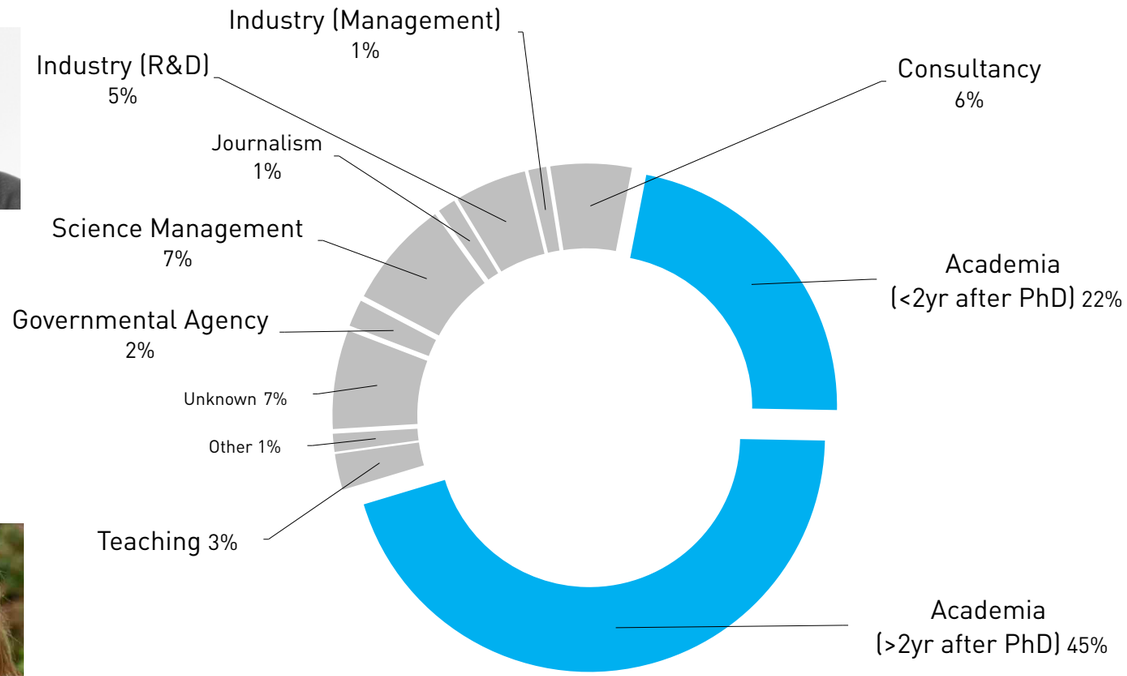
Dr. Nasser Bani Hassan
Senior Geophysicist, ERC Equipoise LtD,
London, UK

For my work it is a huge benefit to see the big picture. The interdisciplinary education at ISOS was a great advantage to communicate across different fields

Dr. Sebastian Krug
Climate Protection Manager,
Rendsburg, Germany

My interdisciplinary marine background allows me to challenge the pupils with realistic, relevant and up-to-date marine questions.

Dr. Katharina Keil
Teacher,
Büsum, Germany



The experiences from my PhD in the Kiel marine community also qualified me for positions outside of academia and helped to get a great position in the IT industry – I especially value the various great courses offered by ISOS.

Dr. Yury Zablotski
IT Consultant, ppi Media,
Kiel, Germany

The interdisciplinary environment in Kiel was invaluable to develop my scientific interests and make important contacts in science.

Dr. Oliver Baars
Scientist, Princeton University,
Princeton, USA

ISOS provided an excellent platform for my personal scientific development as well as a network for collaborative efforts.

Dr. Wiebke Mohr
Scientist, Max Planck Institute for Marine Microbiology,
Bremen, Germany

*Data from May 2016

REFERENCES: DOCTORAL RESEARCHER PROFILES

> Zeynep Erdem (pages 14-15):

[1] Mallon et al. (2012) The response of benthic foraminifera to low-oxygen conditions of the Peruvian oxygen minimum zone. in "ANOXIA", pp. 305-322.

[2] Glock et al. (2011) Environmental influences on the pore density of *Bolivina spissa* (Cushman), Journal of Foraminiferal Research, 41 (1) pp. 22–32.

> Hannah Grant (pages 18-19):

[1] Interridge hydrothermal vent database: http://vents-data.interridge.org/

[2] Herzig, P.M., et al (Eds.), 1998. Proceedings ODP Scientific Results, 158: College Station, TX (Ocean Drilling Program).

> Erik van Doorn (pages 20-21):

[1] Food and Agriculture Organization of the United Nations, The State of World Fisheries and Aquaculture 2014 (Food and Agriculture Organization of the United Nations, Rome; 2014) Part I.

[2] Pardo A, United Nations Document A/C.1/PV.1515, 1 November 1967. [3] Mann Borgese E, The oceanic circle: Governing the seas as a global resource (United Nations University Press, Tokyo etc.; 1998) 11.

> Malte Priess (pages 24-25):

[1] Prieß M., Piwonski J., Koziel S., Oschlies, A, Slawig T (2013) Accelerated Parameter Identification in a 3D Marine Biogeochemical Model Using Surrogate-Based Optimization. Ocean Modelling 68, pp. 22-36

> Sinem Zeytin (pages 26-27):

Results presented here are published in : Zeytin S., Schulz C., Ueberschär B. (2016) Diurnal patterns of tryptic enzyme activity under different feeding regimes in gilthead sea bream (*Sparus aurata*) larvae, Aquaculture 457, pp. 85-90.

> Corinna Breusing (pages 28-29):

Results presented are published in: Breusing C (2016) Population genetics and contemporaneous connectivity in deep-sea hydrothermal vent mussels of the genus Bathymodiolus. Dissertation, Christian-Albrechts-Universität zu Kiel

[1] Ramirez-Llodra E, Brandt A, Danovaro R et al. (2010) Deep, diverse and definitely different: unique attributes of the world's largest ecosystem. Biogeosciences, 7, pp 2851–2899.

> Jan-Lukas Menzel Barraqueta (pages 30-31):

[1] Brown, E T (1996) Estimating dust input to the Atlantic Ocean using surface water aluminium concentrations. in "Impact of desert dust across the Mediterranean", pp. 301-311, Springer Netherlands.

> Martin Hänsel (pages 32-33):

Results presented are published in: Hänsel, Martin C. and Martin F. Quaas (2015). Intertemporal Distribution of Well-Being and Integrated Assessment. Submitted 2015

[1] Nordhaus, W (2010) Economic aspects of global warming in a post-Copenhagen environment. PNAS 107 (26), pp. 11721-11726.

[2] Golosov, Hassler, Krusell, Tsyvinski (2014) Optimal taxes on fossil fuel in general Equilibrium. Econometrica 82 (1), pp. 41-88.

[3] Stern (2007). Stern Review on the Economics of Climate Change, Government Economic Service, London

IMPRINT

/ Concept and Editorial

PD. Dr. Avan Antia, ISOS

Dr. Enno Prigge, ISOS

/ Design and Production

Dr. Enno Prigge, ISOS

/ Print Run

500

First edition July 2016

PICTURE CREDITS

Page 4 (Visbeck): Cluster of Excellence "The Future Ocean", Kiel University

Page 5 (Bleich): M. Bleich

Page 5 (Antia): E. Prigge, ISOS

Pages 14-32 (researcher profile pictures): E. Prigge, ISOS

Page 14 (Schönfeld): J. Schönfeld

Page 16 (Riebesell): D. Ausserhofer, DFG

Page 18 (Hannigton): M. Hannigton

Page 20 (Matz-Lück): M. Beck Fotoproduktion

Page 22 (Schmitz-Streit): J. Haacks, CAU

Page 24 (Slawig): T. Slawig

Page 26 (Schulz): C. Schulz

Page 28 (Reusch): Cluster of Excellence "The Future Ocean", Kiel University

Page 30 (Achterberg): E. Achterberg

Page 32 (Quaas): Cluster of Excellence "The Future Ocean", Kiel University

Page 48 (Hassan): ERC Equipoise Ltd.

Page 48 (Krug): N. Krug

Page 48 (Keil): S. Dwenger

Page 49 (Zablotski): Y. Zablostski

Page 49 (Baars): D. Applewhite, Office of Communications, Princeton University

Page 49 (Mohr): W. Mohr

Icons (page 6): modified after Freepik (distributed by Flaticon)

future ocean
KIEL MARINE SCIENCES

Integrated School of Ocean Sciences (ISOS)
Cluster of Excellence "The Future Ocean"
Kiel University
Leibnizstraße 3
24118 Kiel, Germany
info@isos.uni-kiel.de
www.futureocean.org/en/isos

C|A|U Kiel University Christian-Albrechts-Universität zu Kiel

ifw

muthesius kunsthochschule

GEOMAR